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MODERN SPEECH AMPLIFIER USES 6AS7-G OUTPUT TUBE

KING OF THE KILOWATTS



Amateurs are advised that it is now practical to operate the RCA-833-A at a full kilowatt input in plate-modulated class C telephony service, without the use of forced-air cooling. Typical data for this new natural-air-cooled operation are yours for the asking. Write to Commercial Engineering, RCA, Harrison, N. J.

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EASILY BUILT ELECTRONIC BIAS SUPPLY GIVES REMARKABLE VOLTAGE REGULATION

By GEORGE D. HANCHETT, Jr., W2YM

Zero-bias tubes don't need it, but many of the popular modulator tubes used by Amateurs do require some negative grid bias. The stringent requirement for good voltage regulation makes the problem quite difficult because it rules out the simple type of bleeder-filter circuit. As a result "B" batteries have been used extensively for class "B" modulator bias. However, a review of the literature revealed a better solution to the problem in a paper by George E. Pihl.*

The electronic bias supply described has better voltage regulation than dry batteries. It has greater flexibility, longer life, and is consequently less expensive. Of equal importance, it is a device which can be assembled easily in a few hours by the average Amateur.

Basically, it consists of a small power supply which delivers about 20 ma of current to an output triode. The voltage drop across the triode is used as the regulated bias voltage. Associated with the triode is a pentode dc amplifier and two glow-discharge "VR" tubes which serve to vary the grid voltage of the output triode so that a con-

stant voltage is maintained across it. The voltage regulator tubes take about 20 ma as a "keep-alive current," so the rectifier and filter must supply a total current of about 40 ma.

The theory of operation can be explained by reference to the diagram in Fig. 2. Since the voltage drop across V_1 and V_2 is in parallel with the voltage drop across V_3 and R_1 , any change in voltage across V_1 will appear in its entirety across R_1 , because the voltage drops across both VR tubes remain fixed.

R_1 is the cathode bias resistor of V_3 ; therefore, any voltage change across it appears as a grid voltage change on V_3 . This change in grid voltage is amplified by V_3 and appears across R_2 which is connected

UNIQUE FEATURES OF TWIN TRIODE LEAD TO ITS CHOICE AS AUDIO TUBE

By J. H. OWENS, W2FTW

Something old is something new in speech amplifiers. This latest design reverts to an old-fashioned triode output stage, and dispenses with modern inverse-feedback circuits. Such is the trend of progress!

But regardless of the old fashioned approach in design, the output tube in this amplifier is really ultra-modern. It's the 6AS7-G, a high-power twin-triode that was designed for use in regulated power supplies and television receivers. As an audio tube, it has two features which make it excellent for speech amplifier use:

Extra-low ac plate resistance. Only 560 ohms, plate-to-plate, in a push-pull circuit.

Extra-high plate efficiency. Actually equal in efficiency to multi-grid tubes.

And what is wrong with multi-grid power tubes? Aren't they hum-free even with a mediocre filtered plate supply? Can't they be driven to full output with a very small grid signal? Aren't they exceptionally low in cost?

Yes. In fact, if they are fed into a constant resistance load, there is nothing particularly or peculiarly wrong with them. Unfortunately for radio Amateurs, however, class B modulator grids do not present

a constant impedance. Instead, they are characterized by a constantly varying impedance, and one which varies sharply right during the cycle of an audio frequency signal.

To fully appreciate the importance of this unfavorable situation, consider its relation to one pertinent characteristic of multi-grid power tubes. If the load is removed from a pentode or beam tube power amplifier, the output voltage will rise about five or more times its fully loaded level. Imagine then, the distortion that is generated when one of the modulator grids traverses the threshold from positive to negative voltage.

(Continued on Page 2, Column 1)

STABILITY PLUS STYLE



This functional looking speech amplifier delivers 12 watts of actual power output to a load at less than 4% distortion.

*"A Voltage Stabilized Bias Supply for Power Tubes" by Geo. E. Pihl, Northeastern University Publication Bulletin #10—April 1943.

(Continued on Page 3, Column 4)

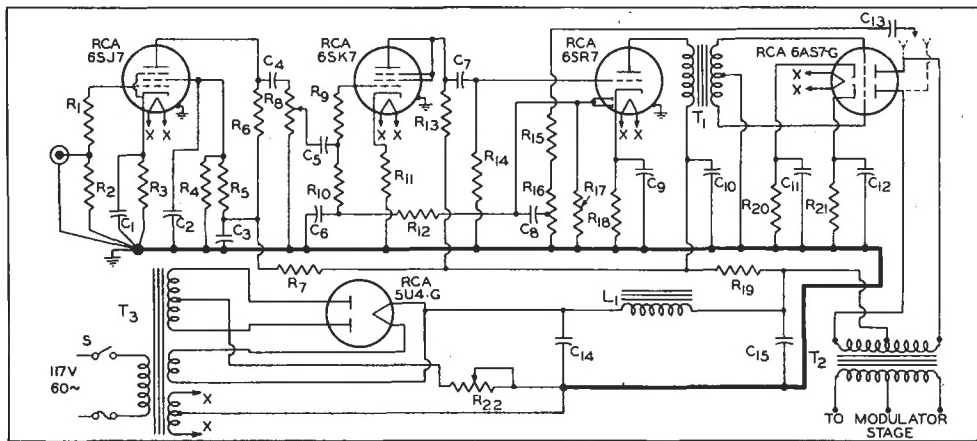


Fig. 1. Schematic of speech amplifier.

SPEECH AMPLIFIER

(Continued from Page 1, Column 4)

In terms of design practice, a speech amplifier must have good voltage regulation of the output signal. This can be achieved by use of tubes, such as the two sections of the 6AS7-G, having very low ac plate resistance. If multi-grid tubes, with a plate resistance of about 100,000 ohms are used, it is necessary to use a great amount of feedback to obtain good regulation. This method is equally satisfactory, providing the feedback loop can be kept degenerative all the way from one cycle to a couple of hundred thousand cycles per second.

If the degenerative condition is not maintained, the amplifier is likely to motor-boat in the familiar "putt-putt" fashion, or voice its displeasure in a strident wail, or it may really cause confusion with random bursts of ultrasonic parasitic oscillations. Radio design engineers, working in manufacturers' laboratories, with the benefit of elaborate test equipment, are able to achieve such a control, but the average Ham shack is not so well equipped.

Pentode Difficulties

The use of a 6AS7-G eliminates pentode feedback difficulties, and at the same time gets around certain objections to filament-type triodes such as the 2A3, 6A3, and 6B4G. These tubes generate filament hum that can't be removed easily without the use of negative feedback. They also produce some distortion in a class AB circuit unless matched tubes are used or a bias correcting network is provided. Furthermore, they do not have the high plate efficiency of beam tubes or the 6AS7-G.

The 6AS7-G eliminates these objections. Filament hum is entirely removed by its heater-cathode construction. There are two triode units in a 6AS7-G and each one has its own cathode which comes out to a separate base pin. It becomes possible, therefore, to use separate cathode bias resistors and by-pass capacitors for each triode, permitting the two sections to be self-

matching. Self-bias balancing of 2A3's would require two filament transformers, one for each tube.

Another important consideration is plate efficiency. For class A, or class AB, service, efficiency is simply related to the position or angle of the zero-bias line on the plate family of curves. Reduced to simple terms, high efficiency is obtained if a tube is able to draw high plate current at low plate voltage when the grid swings to zero. The efficiency is, in effect, a measure of the plate voltage swing that can be obtained with a given plate supply voltage and peak signal plate current.

Circuit Considerations

Reference to the plate family will show that a 6AS7-G plate will swing down to 30 volts when the plate current is 100 ma and the grid is at zero. This is identical to the performance of a 6L6 under equal conditions with a screen grid voltage of 250. By contrast, a 2A3 plate will swing down only to about 90 volts. When the 2A3 is operated with a plate-supply voltage of 300 volts, a half-cycle voltage of about 210 volts can be developed in the plate circuit with a 100 ma swing of plate current. A 6AS7-G will develop 220 volts with the same swing of plate current, but with a plate supply of only 250 volts.

An examination of the circuit design of the amplifier is appropriate at this point. As illustrated in Fig. 1, the schematic is quite conventional. A 6SJ7 was chosen for the input stage because of its high gain, as well as its comparative stability in an rf field.

The second stage tube is a 6SK7, triode connected. This type was chosen because it provides a variable-gain electrode for the injection of a dc compression or AMC voltage.

The third stage is a 6SR7, chosen because it has two diodes. If it were not for the AMC requirement, the type 6J5 would have been used in both the 6SK7 and 6SR7 stages. Plate, grid, and cathode resistors and capacitors would remain the same, but all components in the compression circuit would be omitted, and

the 6SK7 series grid resistor would be connected to the movable arm of the volume control.

The 6SR7 is, of necessity, transformer-coupled to the 6AS7-G. Resistance-coupling will not supply the large grid swing that the 6AS7-G grids require. A transformer might be a disadvantage in an amplifier used for musical reproduction, but it has merit in a speech amplifier since it can be used to control the frequency response characteristic. With all-resistance-coupling, the amplifier response is flat, but the transformer changes the curve and gives it a rising high-frequency characteristic.

If a high-fidelity transformer were used, with parallel choke feed, the response would remain flat, or it could be tilted up at the low end. But when the transformer primary carries the 6SR7 dc plate current, its inductance is reduced. This decreases the impedance at the low-frequency end, reduces the response at that end, and, in effect, tilts up the high end.

Voice Phenomena

If a very small and cheap transformer is used, the effect is emphasized. With a two-pound transformer of intermediate quality, there is just enough high-frequency pre-emphasis to make speech crisp and highly intelligible.

High-frequency pre-emphasis plus bandwidth restriction has been prac-

tised by communication companies for many years. Suppression of fundamental voice frequencies below 400 cycles does not affect the intelligibility or the pitch of speech, but it does remove the sounds which would otherwise absorb 50% or more of the power-handling capabilities of the transmission medium.

To dwell a moment on voice phenomena, it is known that the deeper vowel formants range from approximately 400 to 900 cycles per second. The upper vowel formants go from 900 to about 2400 cps. Then the dominant sibilants occupy the band up to about four or five thousand cps. Within this range of 400 to 5000 cps. are the important sounds that help create and identify spoken words.

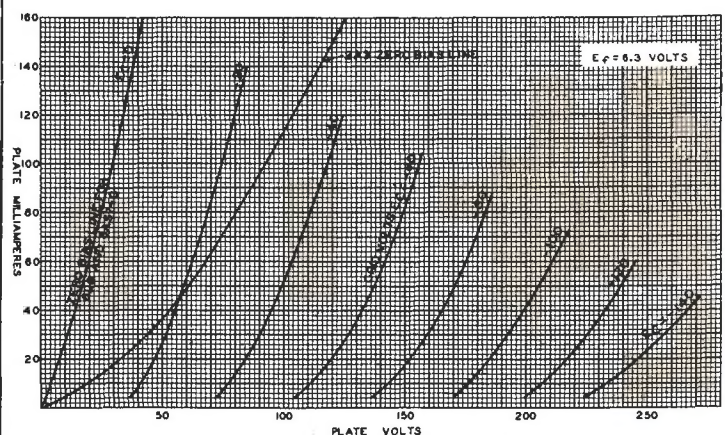
Other Considerations

The development of a story about the new 6AS7-G in a speech amplifier affords the opportunity to review other important design practices. Such things as rf feedback, suppression and hum reduction are too important to be overlooked.

To eliminate rf rectification and feedback, it is only necessary to prevent rf voltages from appearing between the grids and cathodes of the low-level tubes. Shielding is therefore very important, and metal tubes simplify the job. The metal shells are grounded to the chassis with leads as short as practicable.

Series grid resistors are more effective than chokes in keeping rf off of the grid terminals. Quarter- or half-watt carbon units should be used, and the ends going to the socket grid terminals should be clipped short. No other wiring should touch these grid socket terminals. The resistance values given in the parts list for these series grid resistors should be satisfactory for all circumstances, but they may be increased to 100,000 ohms each without ill effects.

Because the point most sensitive to rf feedback is the 6SJ7 grid, it should be examined first if feedback occurs. Incidentally, these grid resistors reduce the response to very high audio frequencies, thereby helping to narrow the channel and keep down the level of modulation splatter.



Average plate characteristics of the 6AS7-G for each triode unit.

Hum and Noise

The grounding system is the most important design factor to observe precisely in the construction of a high-gain amplifier. In fact, there are two grounds, a mechanical ground and an electrical ground. The mechanical ground is the chassis, metal component shields, inductor cores, and the metal tube shells. The electrical ground is the high-voltage dc return path to the center tap of the power transformer. The two grounds are separate, and are joined at only one single point near the input tube.

The electrical ground bus goes from the filter, to the power stage, to the 6SR7, to the 6SK7, to the 6SJ7, and finally to the point of contact with the mechanical ground. All electrical returns are made to it in progression as shown. This is important because it prevents the low-level stages "seeing" minute voltage drops produced by the flow of currents from higher-level stages.

The 6SJ7 returns are the most critical. In order to get high gain with lowest hum, it is necessary to bring the ac and dc grid and cathode returns to a common point. The microphone cable shield also grounds at this point rather than at the chassis where the microphone jack is located. The jack must be insulated from the chassis. From this final terminal point in the electrical ground system, a short wire goes to a convenient point on the chassis ground near the 6SJ7 socket.

The 6SJ7 is also the most critical tube for microphonics. To keep such noises at a minimum, the tube is cushion mounted on rubber grommets. On the same cushioned socket mounting plate are solderlug terminal strips on which all of the associated resistors and capacitors are mounted. Connections from these to other parts of the circuit are made through flexible "test lead" wires.

The Filter

One disadvantage of low- μ output triodes is that they require a well filtered plate supply. The filter choke must be employed as shown because a large portion of any power supply ripple will be transmitted by the tubes through the output transformer to the modulator grids.

One precaution to observe in designing the filter is to make sure that the main capacitor pack does not use the container can as the negative terminal. If it does, the can will have to be insulated from the chassis to preserve separate electrical and mechanical grounds.

There is little need for good power supply regulation in this amplifier because the power tubes are operated in class A. Even at full signal, the total plate current rises only a few milliamperes; large voltage fluctuations are not therefore encountered.

The AMC Circuit

Provision for volume compression was incorporated in the amplifier because it can be quite beneficial when used with discretion. If the compression control is set so that the 6SR7 diodes begin to rectify at about 80% to 90% modulation, and if the volume control is advanced about 3 db higher than its normal position, the AMC circuit will help prevent overmodulation. If the time-delay circuit is not too slow, it may also increase the loudness of carelessly "swallowed" words, thereby improving to a certain extent the average intelligibility of transmitted signals.

A word of caution. Too much compression is readily possible. If the gain control is advanced more than 6 db and if the compression control is set so that rectification starts below the level of 75% modulation, an effect of blooming, burping, and gasping speech will be created. Words will start ex-

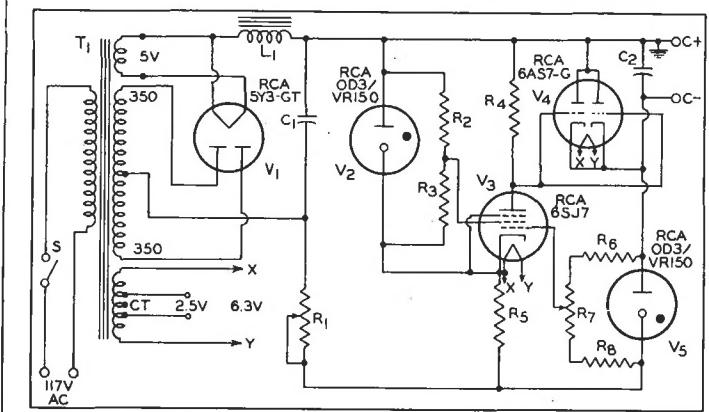


Fig. 2. Schematic of electronic bias supply.

sively and end faintly. Furthermore, overmodulation will occur.

There is one special precaution to be taken in the compressor wiring. For best results, it is essential that a voltage of proper phase be delivered to the 6SR7 diodes, otherwise the gainshift "bloops" will be over-emphasized.

To get the right connection, disconnect bypass capacitor C6 and try the plate coupling capacitor C13 on first one and then the other 6AS7-G plate. One connection will cause some hum and a tendency to motor boat or howl. The other connection, the right one, may cause the amplifier to oscillate at some high frequency, but will tend to suppress any hum or low-frequency noises. It does this because it provides some inverse feedback at very low frequencies. With the time-constant capacitor C6 back in the circuit, the effect of the feedback is small, but beneficial.

The amplifier is so stable that the mechanical design layout is unimportant. As shown, this unit is built on a 12" x 3" x 7" chassis. On top of the chassis are the power transformer, interstage transformer, main capacitor pack, output transformer, and the tubes. The filter choke and other components are mounted underneath in convenient locations.

This new amplifier will deliver twelve watts of actual power output to a load at less than 4% distortion. This is adequate to drive any of the class B modulator tubes used in conjunction with a one-kilowatt final amplifier, with plenty of power to spare.

PARTS LIST

R1	47000 ohms, 1/2 watt
R2	2 Meg., 1/2 watt
R3	1000 ohms, 1/2 watt
R4	120000 ohms, 1 watt
R5	680000 ohms, 1 watt
R6	220000 ohms, 1 watt
R7	33000 ohms, 2 watts
R8	500000 ohms, grid-taper pot
R9	47000 ohms, 1/2 watt
R10	390000 ohms, 1/2 watt
R11	2200 ohms, 1/2 watt
R12	560000 ohms, 1/2 watt
R13	150000 ohms, 1 watt
R14	270000 ohms, 1/2 watt
R15	82000 ohms, 1 watt
R16	50000 ohms, pot, wire-wound
R17	560000 ohms, 1/2 watt
R18	1200 ohms, 1/2 watt
R19	10000 ohms, 4 watts, wire-wound
R20	2500 ohms, 10 watts, wire-wound
R21	2500 ohms, 10 watts, wire-wound

R22 200 ohms, 10 watts, wire-wound

C1, C9 10 μ f, 25 volts
C2 0.1 μ f, 400 volts
C3 0.25 μ f, 400 volts
C4, 5, 7, 8 0.05 μ f, 600 volts
C6 0.1 μ f, 200 volts
C10 8 μ f, 450 volts
C11, 12 12 μ f, 150 volts
C13 0.1 μ f, 600 volts
C14, 15 20 μ f, 450 volts

T1 Thordarson T-20A22 or Stancor A-83-C
T2 Stancor A-4761, A4762, or equivalent
T3 Halldorson 74-S, or equivalent
L1 10 h at 125 ma

ELECTRONIC BIAS SUPPLY

(Continued from Page 1, Column 2)

directly to the plate of V₃ and the grids of the output tube V₄. This change in voltage swings the grid of V₄ more positive or negative and thus varies the internal resistance of tube V₄, maintaining the drop across it practically constant.

The unit shown in the schematic diagram will provide a regulated bias voltage adjustable from 30 to 80 volts, and will handle a rectified grid current up to approximately 200 ma. The unit can be adjusted down to 20 volts but at this voltage only about 100 ma can be handled. This voltage range covers the grid-bias requirements of nearly all the tubes used by Amateurs as class B modulators.

For those amateurs who are interested in the performance of the regulator the calculated voltage regulation is 0.001 volts/ma. This means that when the supply is set to, say, 45 volts a grid current of 200 ma through it will cause the bias voltage to rise to 45.2 volts. This change is so very small that it is not perceptible on the meter.

PARTS LIST

R1	5000 ohms, 25 watts, wire-wound
R2	24000 ohms, 1/2 watt
R3	68000 ohms, 1/2 watt
R4	270000 ohms, 1/2 watt
R5	3000 ohms, 5 watts, wire-wound
R6	120000 ohms, 1/2 watt
R7	100000 ohms, potentiometer
R8	27000 ohms, 1/2 watt
C1	20 μ f, 450 volts
C2	20 μ f, 150 volts
L1	8 h at 50 ma (ac/dc replacement choke)
T1	Thordarson T-13R20 or UTC R-11; 350-0-350 at 50 ma; 5 volts at 2 amps; 6.3 volts at 3 amps
S	Single pole, single throw toggle switch



The electronic bias supply shown above provides a regulated bias voltage adjustable from 30 to 80 volts and handles a rectified grid current up to 200 ma.



RCA-6AS7-G LOW MU TWIN POWER TRIODE

Amateur Net

\$5.48

Reduced To
\$4.25

Features

- High Efficiency. Usable plate swing is almost equal to plate voltage.
- Good Stability. Low amplification factor insures freedom from regeneration.
- Two Cathodes. Allows use of self-bias balancing of the two triode units.
- Low Distortion. Even harmonics almost cancel in class A push-pull circuits.
- Excellent Voltage Regulation. Output signal varies but slightly with change in load.
- Twin-Unit Construction. Provides circuit layout convenience.
- In voltage regulator service, a load current of 250 ma can be controlled with one 6AS7-G. Because of the 300-volt heater-to-cathode rating, no separate filament winding is needed.
- In bias regulator service, the tube's low internal resistance allows regulation as low as 20 volts.

Application Considerations

The following recommended practices should be observed when the 6AS7-G is used in audio-frequency amplifier applications.

1. The two units should always be used in push-pull, never parallel.
2. Always use self bias; fixed bias must not be used.
3. Separate cathode bias resistors, and by-pass capacitors, should be used for each unit.
4. The total series grid resistance, per unit, should be limited to one megohm.
5. Transformer, or impedance-coupling devices should be used in order to get sufficient voltage to fully swing the grids.
6. The transformer-coupled driver tube should be a medium-mu triode such as the 6J5, 6SR7, 6C4, 6SN7, 12AU7, etc. For self-biased operation of the driver tube, by-pass its cathode resistor with a capacitance of 8 uf or more.
7. The plate supply voltage for the driver tube should be at least 250 volts in order to obtain sufficient grid swing for the 6AS7-G.
8. In a voice-frequency speech amplifier using a single driver tube, the plate of the driver tube can be series-fed through the primary winding of the interstage push-pull transformer.
9. In wide-band, flat-response, audio amplifier service, the grids can be excited by:
 - (a) a push-pull stage through a high-fidelity push-pull interstage transformer.
 - (b) a push-pull stage through a center-tapped plate choke, capacitance-coupled to resistor-fed grids.
 - (c) a single tube with choke-fed plate, through a capacitance-coupled single-plate-to-push-pull-grids high-fidelity transformer.

6AS7-G LOW-MU TWIN POWER TRIODE

GENERAL DATA

Electrical:	
Heater, for Unipotential Cathode:	
Voltage	6.3 ac or dc volts
Current	2.5 amp.
Mechanical:	
Mounting Position	any
Maximum Overall Length	5-5/16"
Maximum Seated Length	4-3/4"
Maximum Diameter	2-1/16"
Bulb	ST-16
Base	Medium Shell Octal 8-Pin

AUDIO AMPLIFIER SERVICE

Values are for each unit

Maximum Ratings, Design Center Values:

PLATE VOLTAGE	250 max.	volts
PLATE CURRENT	125 max.	ma
PLATE DISSIPATION	13 max.	watts
PEAK HEATER-CATHODE VOLTAGE		
Heater negative with respect to cathode	300 max.	volts
Heater positive with respect to cathode	300 max.	volts
Typical operation, Class A ₁ push-pull amplifier. Unless otherwise specified, values are for both units.		
Plate	200	250 volts
Grid	-90	-125 volts
Cathode Resistor (per unit)	1500	2500 ohms
Peak AF grid to grid voltage	190	255 volts
Zero signal plate current	120	100 ma
Max. signal plate current	128	106 ma
Effective load resistance (plate to plate)	4000	6000 ohms
Total harmonic distortion (less than)	4	4 per cent
Max. signal power output	11	13 watts
Amplification Factor (per unit)	2.0	2.0
Plate Resistance (per unit)	280	280 ohms

- It is essential that precaution be taken in equipment design to prevent subjecting the tube to full load current of 250 ma before its cathodes have reached normal operating temperature. The cathodes require approximately 15 seconds to attain normal operating temperature. Unless this precaution is observed, the cathodes will be seriously damaged, if not completely ruined. In speech amplifier service, as indicated under typical operating conditions, the plate voltage may be applied simultaneously with the filament voltage.

HAM TIPS is published by the RCA Tube Department, Harrison, N. J., and is made available to Amateurs and Radio Experimenters through RCA tube and parts distributors.

J. H. OWENS, W2FTW Editor
H. S. STAMM, W2WCT Associate Editor